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(54) **OPERATING CIRCUIT APPLIED TO BACKLIGHT AND ASSOCIATED METHOD**

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(58) **Field of Classification Search**
CPC H05B 33/0815; H05B 33/0827; H05B 37/02; Y02B 20/347
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0094008 A1*	4/2008	Liu	315/294
2008/0144236 A1*	6/2008	Chiang et al.	361/18
2010/0264837 A1*	10/2010	Zhao	315/189

FOREIGN PATENT DOCUMENTS

CN	101207958 A	6/2008
TW	200820177	5/2008
TW	200822029	5/2008
TW	200832331	8/2008
TW	201044916	12/2010

* cited by examiner

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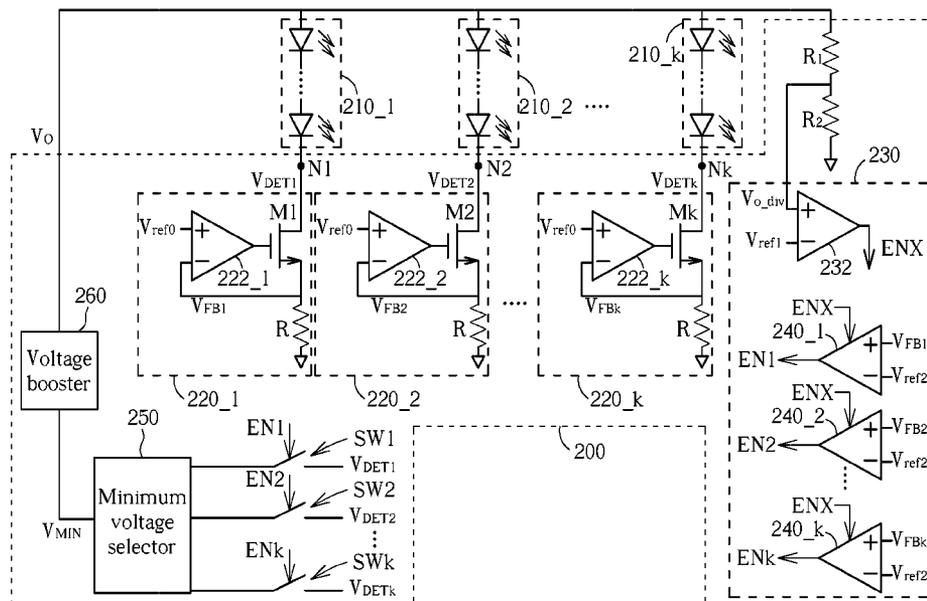
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(57) **ABSTRACT**

An operating circuit applied to a backlight is provided, where the backlight includes a plurality of lighting elements, and the operating circuit includes a plurality of current control circuits, a plurality of switches, a minimum voltage selector, a supply voltage generating circuit and a control unit. The current control circuits are coupled to the lighting elements via a plurality of nodes, respectively. The switches are coupled to the nodes, respectively. The minimum voltage selector is utilized for receiving at least a portion of voltages of the plurality of nodes, and selecting a minimum voltage among the received voltages. The supply voltage generating circuit is utilized for generating a supply voltage of the lighting elements according to the minimum voltage. For each of the switches, the control unit determines an on/off state of the switch by determining whether the corresponding lighting element is an open circuit or not.

8 Claims, 3 Drawing Sheets



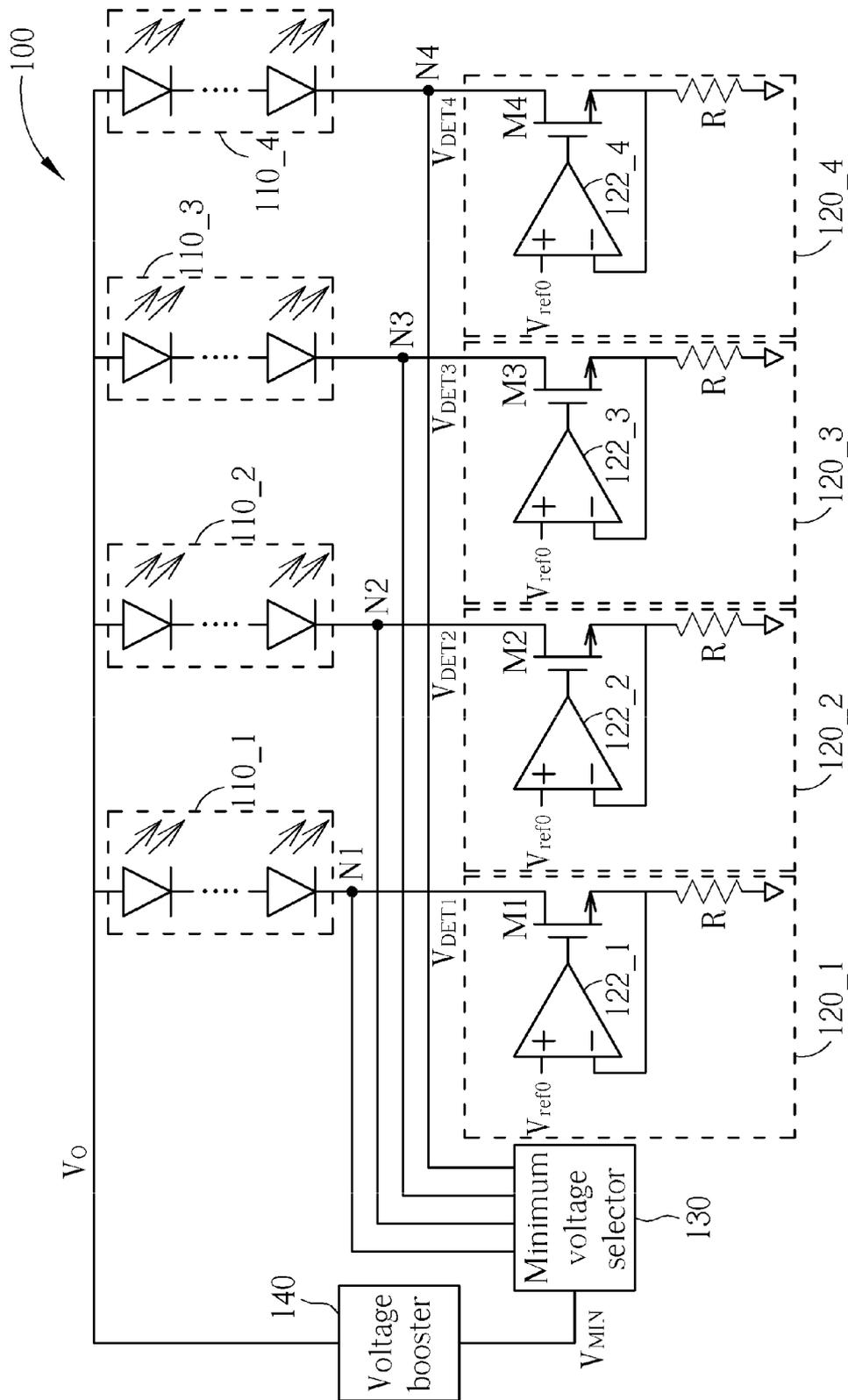


FIG. 1 PRIOR ART

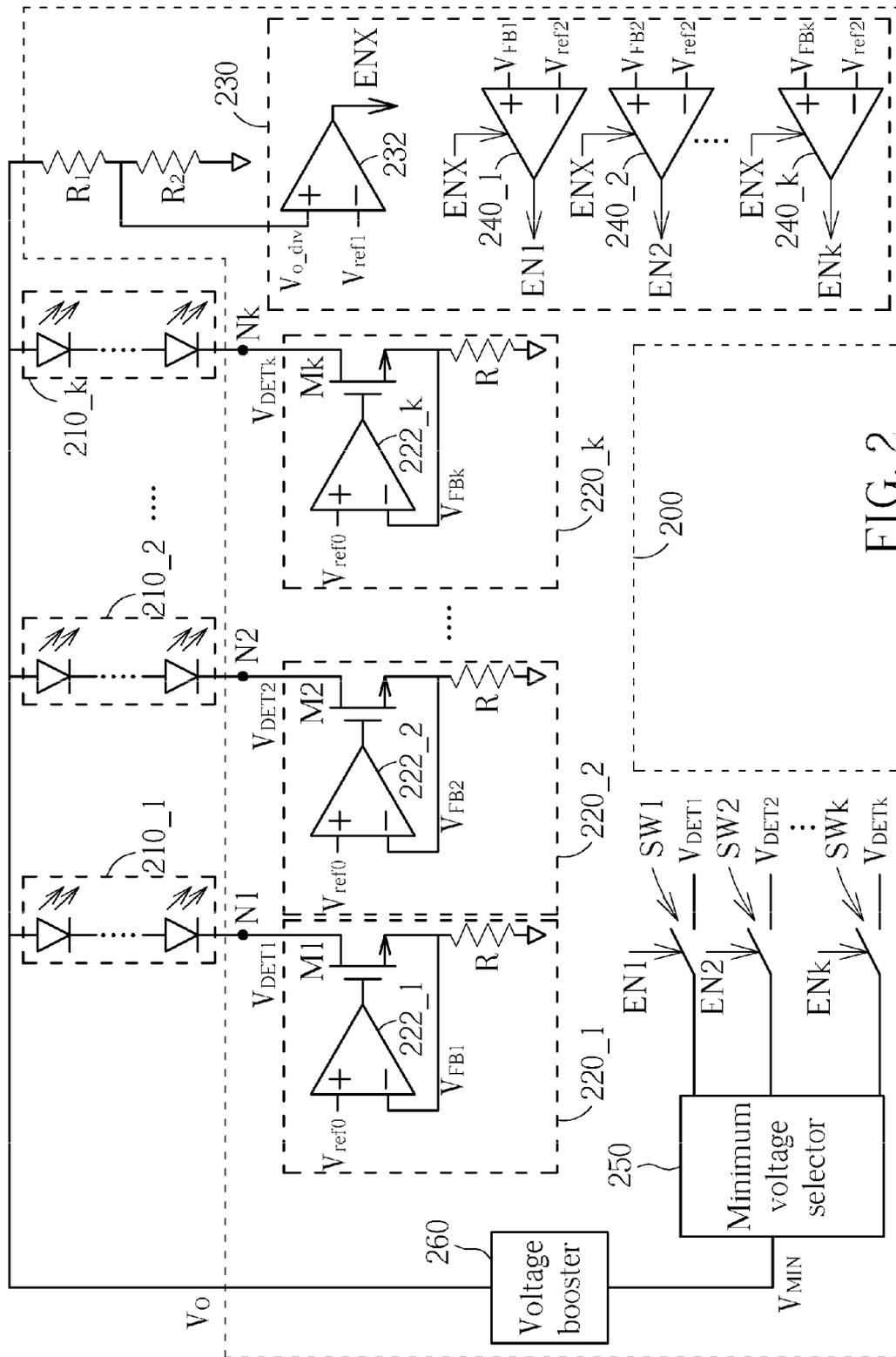


FIG. 2

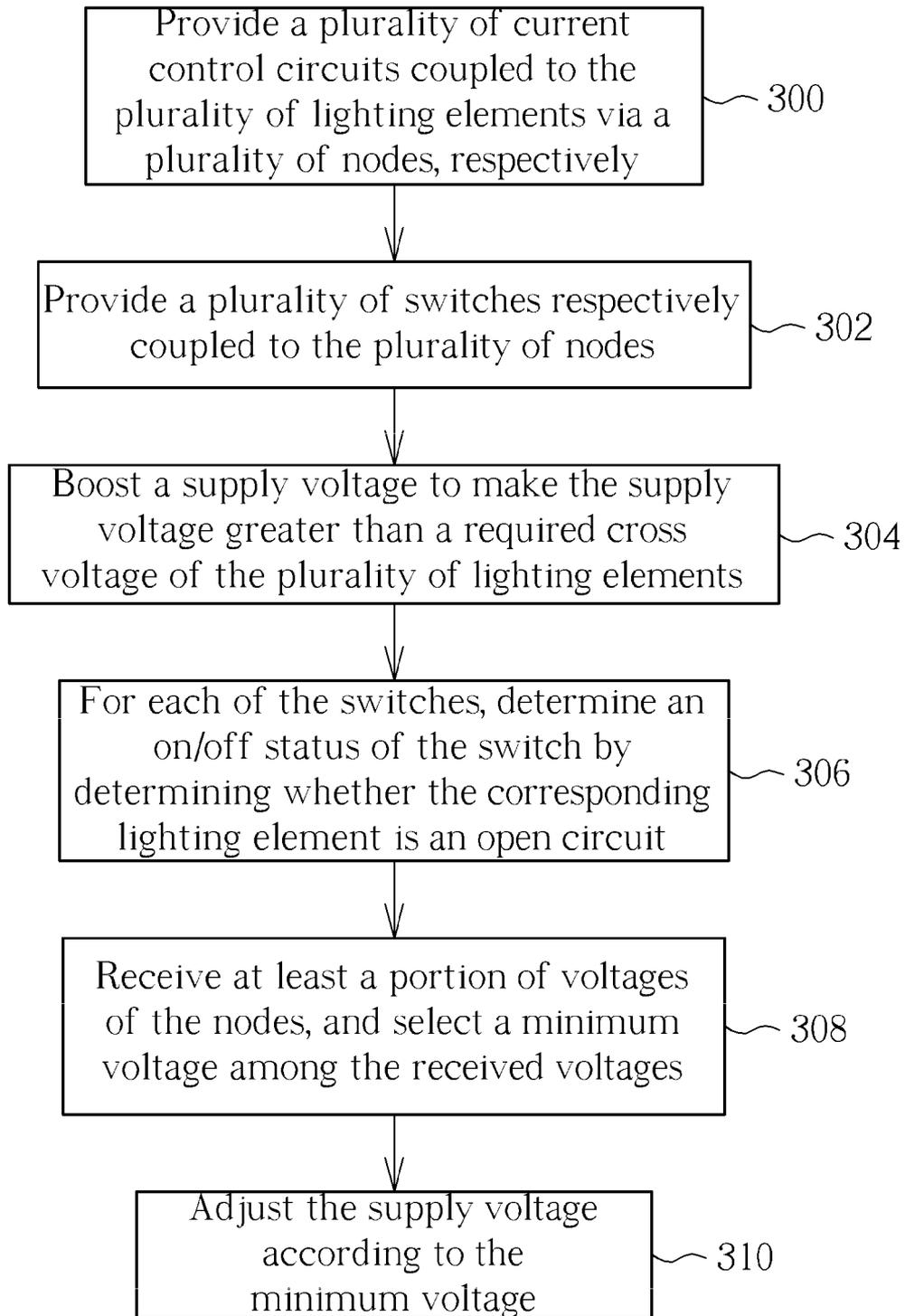


FIG. 3

OPERATING CIRCUIT APPLIED TO BACKLIGHT AND ASSOCIATED METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an operating circuit applied to a backlight, and more particularly, to an operating circuit applied to a light-emitting diode (LED) backlight.

2. Description of the Prior Art

Please refer to FIG. 1, which illustrates a prior art backlight module control system **100**. As shown in FIG. 1, the backlight module control system **100** includes a plurality of LED strings **110_1-110_4**, a plurality of current control circuits **120_1-120_4**, a minimum voltage selector **130** and a voltage booster **140**, where each of the LED strings **110_1-110_4** includes a plurality of LEDs, and each of the current control circuits **120_1-120_4** includes an amplifier (**122_1-122_4**), a transistor (**M1-M4**) and a resistor R.

Because each of the LEDs has a semiconductor process variation, the cross voltages of the LED strings **110_1-110_4** are different while the LED strings **110_1-110_4** are working. To confirm each of the LED strings **110_1-110_4** has enough cross voltage while working, the minimum voltage selector **130** selects a minimum voltage among the voltages $V_{DET1}-V_{DET4}$ of the nodes N1-N4, and the voltage booster **140** determines a supply voltage V_0 of the LED strings **110_1-110_4** according to the minimum voltage. In other words, the backlight module control system **100** determines the supply voltage V_0 of the LED strings **110_1-110_4** by referring to the LED string having a largest cross voltage so as to make each of the LED strings **110_1-110_4** have enough cross voltage.

However, when one of the LED strings **110_1-110_4** is burned out (i.e., being an open circuit), the corresponding voltage V_{DET} will always be zero. Then, because the minimum voltage V_{MIN} outputted from the minimum voltage selector **130** is always zero, the voltage booster **140** will continuously boost the supply voltage V_0 until an over voltage protection mechanism is triggered to close the operations of the backlight module control system **100**, causing the failure of the control mechanism.

SUMMARY OF THE INVENTION

It is therefore an objective of the present invention to provide an operating circuit applied to a backlight to prevent the control mechanism from being failed due to the burned out LED.

According to one embodiment of the present invention, an operating circuit applied to a backlight is provided, where the backlight includes a plurality of lighting elements, and the operating circuit includes a plurality of current control circuits, a plurality of switches, a minimum voltage selector, a supply voltage generating circuit and a control unit. The current control circuits are coupled to the lighting elements via a plurality of nodes, respectively. The switches are coupled to the nodes, respectively. The minimum voltage selector is utilized for receiving at least a portion of voltages of the plurality of nodes, and selecting a minimum voltage among the received voltages. The supply voltage generating circuit is utilized for generating a supply voltage of the lighting elements according to the minimum voltage. For each of the switches, the control unit determines an on/off state of the switch by determining whether the corresponding lighting element is an open circuit or not.

According to another embodiment of the present invention, an operating method applied to a backlight is provided, where

the backlight comprises a plurality of lighting elements, each of the lighting elements comprises at least one lighting unit, and the operating method comprises: providing a plurality of current control circuits, coupled to the plurality of lighting elements via a plurality of nodes, respectively; providing a plurality of switches, coupled to the plurality of nodes, respectively; boosting a supply voltage to make the supply voltage greater than a required cross voltage of the plurality of lighting elements; for each of the switches, determining an on/off state of the switch by determining whether the corresponding lighting element is an open circuit; receiving at least a portion of voltages of the nodes, and select a minimum voltage among the received voltages; and adjusting the supply voltage according to the minimum voltage.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating a prior art backlight module control system.

FIG. 2 is a diagram illustrating an operating circuit applied to a backlight according to one embodiment of the present invention.

FIG. 3 is a flowchart of an operating method applied to a backlight according to one embodiment of the present invention.

DETAILED DESCRIPTION

Please refer to FIG. 2, which illustrates an operating circuit **200** applied to a backlight according to one embodiment of the present invention, where the backlight includes a plurality of lighting elements, and each of the lighting elements includes at least one lighting unit. In this embodiment, each lighting unit is an LED, and the lighting elements are LED strings **210_1-210_k**. As shown in FIG. 2, the operating circuit **200** includes a plurality of current control circuits **220_1-220_k**, two resistors R_1 and R_2 , a control unit **230**, a plurality of switches SW1-SW k , a minimum voltage selector **250** and a supply voltage generating circuit, wherein the supply voltage generating circuit is implemented by a voltage booster **260** in this embodiment. The current control circuit **220_1-220_k** are coupled to the LED strings **210_1-210_k** via nodes N1-N k , respectively, and each of the current control circuit **220_1-220_k** includes an amplifier (**222_1-222_k**), a transistor (M1-M k) and a resistor R. The control unit **230** includes a first comparator **232** and a plurality of second comparators **240_1-240_k**.

The resistors R_1 and R_2 divide the supply voltage V_0 of the LED strings **210_1-210_k** to generate a divided voltage V_{0_div} . Then the first comparator **232** compares the divided voltage V_{0_div} with a first reference voltage V_{ref1} to generate a comparison signal ENX. The first reference voltage V_{ref1} can be set according to a standard cross voltage of the LED strings **210_1-210_k** provided by the client. In one embodiment, the first reference voltage V_{ref1} is set a little lower than a divided standard cross voltage divided by the resistors R_1 and R_2 , and when the divided voltage V_{0_div} is greater than the first reference voltage V_{ref1} , it is represented that the supply voltage V_0 is greater than the required cross voltage of the LED strings **210_1-210_k** and all the LED strings **210_1-210_k** can be operated normally, at this time, the comparison signal ENX outputted from the first comparator **232** is "1",

and the second comparators **240_1-240_k** are enabled. On the other hand, when the divided voltage V_{o_div} is not greater than the first reference voltage V_{ref1} , it is represented that the cross voltages of LED strings **210_1-210_k** may not be large enough to make all the LED strings **210_1-210_k** operated normally, at this time, the comparison signal ENX outputted from the first comparator **232** is "0", and the second comparators **240_1-240_k** are disabled.

When the second comparators **240_1-240_k** are enabled, the second comparators **240_1-240_k** compare a plurality of feedback voltages $V_{FB1}-V_{FBk}$ of the amplifiers **222_1-222_k** with a second reference voltage V_{ref2} to determine if one or more LED strings **210_1-210_k** are burned out (i.e., be an open circuit) to generate switch control signals EN1-ENk to control the switches SW1-SWk, respectively. For example, if the LED string **210_1** is open, the voltage V_{DET1} of the node N1 and the feedback voltage V_{FB1} will be zero, and the switch control signal EN1 outputted from the second comparator **240_1** is "0", and the switch SW1 is switched off. If the LED string **210_1** is not open, the voltage V_{DET1} of the node N1 and the feedback voltage V_{FB1} will be greater than zero (because the input terminals of the amplifier **222_1** are virtual ground, the feedback voltage V_{FB1} is equal to a reference voltage V_{ref0}), and the switch control signal EN1 outputted from the second comparator **240_1** is "1", and the switch SW1 is switched on. In a preferred embodiment, the second reference voltage V_{ref2} is set to be 1 V, and each of the LED strings **210_1-210_k** can be determined as an open circuit by determining whether the corresponding feedback voltage ($V_{FB1}-V_{FBk}$) is lower than the second reference voltage V_{ref2} . In other embodiments, the second reference voltage V_{ref2} can be any value between the reference voltage V_{ref0} and 0V.

In other embodiments, the first reference voltage V_{ref1} is set a little greater than the divided standard cross voltage divided by the resistors R_1 and R_2 . That is, the second comparators **240_1-240_k** are enabled after the supply voltage V_o is boosted. When the second comparators **240_1-240_k** are disabled, the switches SW1-SWk are kept switched on, and only after the second comparators **240_1-240_k** are enabled, the switches SW1-SWk are controlled by the switch control signals EN1-ENk, respectively.

In light of above, by referring to the statuses of the switches SW1-SWk respectively controlled by the switch control signals EN1-ENk, the minimum voltage selector **250** receives at least a portion of the voltages $V_{DET1}-V_{DETk}$ of the nodes N1-Nk. If the LED string **210_1** is open, the switch control signal EN1 switches off the switch SW1 to make the minimum voltage selector **250** not receive the voltage V_{DET1} , and the switch control signals EN2-ENk switch on the switches SW2-SWk, respectively, to make the minimum voltage selector **250** receive the voltages $V_{DET2}-V_{DETk}$. Therefore, the minimum voltage selector **250** can output the correct minimum voltage V_{MIN} to the voltage booster **260** to adjust the supply voltage correctly.

During the period that the divided voltage V_{o_div} is not greater than the first reference voltage V_{ref1} (e.g., the operating circuit **200** is enabled a short time ago), it is meant that the supply voltage V_o is lower than the required cross voltage of the LED strings **210_1-210_k**. As the cross voltages of the LED strings **210_1-210_k** are not enough, the switches SW1-SWk are switched off, the minimum voltage selector **250** does not receive any one of the voltages $V_{DET1}-V_{DETk}$ of the nodes N1-Nk, the minimum voltage selector **250** does not output the minimum voltage V_{MIN} , and the voltage booster **260** does not receive the minimum voltage V_{MIN} . In this embodiment, the voltage booster **260** has a fast boosting mechanism (not shown) to fast boost the supply voltage V_o

when the voltage booster **260** does not receive the minimum voltage V_{MIN} . After the divided voltage V_{o_div} is greater than the first reference voltage V_{ref1} , the LED open circuit determining mechanism is enabled, the minimum voltage selector **250** starts to provide the minimum voltage V_{MIN} , and the voltage booster **260** starts to adjust the supply voltage V_o according to the minimum voltage V_{MIN} .

In addition, in the embodiment shown in FIG. 2, the switch control signals EN1-ENk are generating by comparing the feedback voltages $V_{FB1}-V_{FBk}$ with the second reference voltages V_{ref2} , respectively. However, it is not meant to be a limitation of the present invention. In another embodiment of the present invention, the second comparators **240_1-240_k** can compare the voltages $V_{DET1}-V_{DETk}$ with the second reference voltage V_{ref2} to generate the switch control signals EN1-ENk, respectively. This alternative design should fall within the scope of the present invention.

Please refer to FIG. 3, which is a flowchart of an operating method applied to a backlight according to one embodiment of the present invention, where the backlight includes a plurality of lighting elements, and each of the lighting elements includes at least one lighting unit. Referring to FIG. 2 and FIG. 3, the flow is described as follows.

Step **300**: provide a plurality of current control circuits coupled to the plurality of lighting elements via a plurality of nodes, respectively.

Step **302**: provide a plurality of switches respectively coupled to the plurality of nodes.

Step **304**: boost a supply voltage to make the supply voltage greater than a required cross voltage of the plurality of lighting elements.

Step **306**: for each of the switches, determine an on/off state of the switch by determining whether the corresponding lighting element is an open circuit.

Step **308**: receive at least a portion of voltages of the nodes, and select a minimum voltage among the received voltages.

Step **310**: Adjust the supply voltage according to the minimum voltage.

Briefly summarized, in the operating circuit and associated method of the present invention, a LED string is detected to determine whether the LED string is an open circuit. Then, if the LED string is determined as the open circuit, its corresponding voltage will not be used to determine the minimum voltage. Therefore, the operating circuit can determine the supply voltage of the LED strings correctly.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

1. An operating circuit applied to a backlight, wherein the backlight comprises a plurality of lighting elements, each of the lighting elements comprises at least one lighting unit, and the operating circuit comprises:

a plurality of current control circuits, coupled to the plurality of lighting elements via a plurality of nodes, respectively;

a plurality of switches, coupled to the plurality of nodes, respectively;

a minimum voltage selector, coupled to the plurality of switches, for receiving at least a portion of voltages of the plurality of nodes, and selecting a minimum voltage among the received voltages;

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a supply voltage generating circuit, coupled to the minimum voltage selector, for generating a supply voltage of the plurality of lighting elements according to the minimum voltage; and

a control unit, coupled to the plurality of switches and the supply voltage generating circuit, wherein for each of the switches, the control unit determines an on/off state of the switch by determining whether the corresponding lighting element is an open circuit or not;

wherein the control circuit comprises:

- a plurality of second comparators, for generating a plurality of switch control signals by comparing the voltages of the plurality of nodes with a second reference voltage, respectively; and
- a first comparator, for determining whether to enable the plurality of second comparators or not by detecting if the supply voltage is greater than a first reference voltage, wherein when the supply voltage is greater than the first reference voltage, the second comparators are enabled; and when the supply voltage is not greater than the first reference voltage, the second comparators are disabled;

wherein the plurality of switch control signals are utilized for switching on or switching off the plurality of switches, respectively.

2. The operating circuit of claim 1, wherein the voltage corresponding to the node is the voltage of the node.

3. The operating circuit of claim 1, wherein the voltage corresponding to the node is a feedback voltage of the corresponding current control circuit.

4. The operating circuit of claim 1, wherein each light unit is a LED, and each of the lighting elements is a LED string.

5. An operating method applied to a backlight, wherein the backlight comprises a plurality of lighting elements, each of the lighting elements comprises at least one lighting unit, and the operating method comprises:

- providing a plurality of current control circuits, coupled to the plurality of lighting elements via a plurality of nodes, respectively;
- providing a plurality of switches, coupled to the plurality of nodes, respectively;

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boosting a supply voltage to make the supply voltage greater than a required cross voltage of the plurality of lighting elements;

for each of the switches, determining an on/off state of the switch by determining whether the corresponding lighting element is an open circuit;

receiving at least a portion of voltages of the nodes, and select a minimum voltage among the received voltages; and

adjusting the supply voltage according to the minimum voltage;

wherein the step of determining the on/off state of the switch by determining whether the corresponding lighting element is the open circuit comprises:

- determining whether a divided voltage of the supply voltage is greater than a first reference voltage to generate a comparison signal;
- providing a plurality of second comparators, wherein when the comparison signal indicates that the divided voltage of the supply voltage is greater than the first reference voltage, the plurality of second comparators are enabled, and when the comparison signal indicates that the divided voltage of the supply voltage is not greater than the first reference voltage, the plurality of second comparators are disabled;

wherein when the plurality of second comparators are enabled, the plurality of second comparators generate a plurality of switch control signals by comparing the voltages of the plurality of nodes with a second reference voltage, respectively, where the plurality of switch control signals are utilized for switching on or switching off the plurality of switches, respectively.

6. The operating method of claim 5, wherein the voltage corresponding to the node is the voltage of the node.

7. The operating method of claim 5, wherein the voltage corresponding to the node is a feedback voltage of the corresponding current control circuit.

8. The operating method of claim 5, wherein each light unit is a LED, and each of the lighting elements is a LED string.

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